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CONSTRUCTION OF A SOLAR SCHOOL BUILDING AND SOLAR RETROFITTING OF AN EXISTING SCHOOL BUILDING

Prepared for

MONTANA DEPARTMENT of NATURAL RESOURCES and CONSERVATION

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CONSTRUCTION OF A SOLAR SCHOOL BUILDING AND SOLAR RETROFITTING OF AN EXISTING SCHOOL BUILDING

Prepared by

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July, 1983

Prepared for

Montana Department of Natural Resources and Conservation
32 South Ewing, Helena, Montana 59620
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Project Abstract

Through class instruction the Vo-Ag students studied and helped design the purposed system. It is felt that energy conservation is a necessary consideration in a building design. We wished to make a model of this project in order that the people in our community be more aware of the energy conservation movement.

The objectives, therefore of this project are:

1. Meet the educational needs of the students
2. An educational approach to the planning, designing, construction of a solar heated building.
3. Making the community aware of the need of solar energy for future needs by creating a model in the school system.
4. Through the use of the media, open house; educational tours display and provide information concerning our active solar system.
5. Allow grades K-12 to observe through tours and demonstrations how a solar renewable energy source works.

Background Information

A Solar Heating System takes advantage of the most constant and abundent supply of useable energy available; the sun by tapping this resource we can accomplish two major objectives.

With school costs contunuing to rise and school district mill levy issues becoming more difficult to pass, any attempt to stabilize the cost involved in a school system will reap future security for the system and help defray present operating costs. Installing an active solar heating system will help achieve those goals.

Secondly and also important, is the information and knowledge that can be obtained from this project. Not only do we have a model for other school districts to evaluate and, possible emulate, but the potential for use as a source of public and educational information is tremendous. The school district can use the system to show the communtiy that alternative energy sources are viable and do work. The school itself will be able to use the facility to supplement any discussions of ther energy situation.

Schools in general and our Vocational and Agricultural program in particular can use this as an example of what can be accomplished in the field of energy conservation and alternative energy and to show how we can help lessen our dependency on unstable and uncertain sources of energy.

Information obtained on the effectiveness of this system can be shared with other large buildings, particularly Bo-Ag shops, that are located in the state of Montana.

The Vocational Agriculture department because of its position of education in the communittee, is highly visible due to its traffic of students, school board members, parents and occasionally political people.

We feel the need for the use and understanding of renewable resources is a top priority of every ones concern. As an educational Institution we wished to do our part in energy conservation and act as a model to the community and other schools. With the monotoring equipment provided, we hope to show the fesibility of an active solar systems. We hope to educate the public as to its importance and ergency in order to be energy self sufficient.

Sources of Information:

While studying the idea of solar energy and alternate methods in a Senior carpentry class we asked a gentlemen from Western Sun to come in and give a lecture on alternative energy means. That is when we became aware of the grant possibility. We then contacted Solar Works, Inc., the engineering consultants for the project to help us design a system that would be fesible and inovative to the industry. Working with us we were able to design a system that was attractive and would meet the grant criteria. They then worked with the architect in implementing their system into the total building project. Enclosed in the exhibits section is literary documents on the system.

Technical Description

The school itself did not do the project but the grantee will provide as much assistance in the technical area as possible. The engineering consultants provided us with literature concerning the project which can be found in the appendix section. The following statements will be as we viewed the project.

By viewing appendix 4, page 1, of the blue print, I will briefly explain the concept of the system.

A sub-grade storage tank is installed in the new addition to contain water that is used in the heating process for this project. Boiler treated water will be circulated from this storage tank through 14 American Solar King Collectors, located on the roof of the structure at a 60° angle, to ne heated. After passing through the collectors the now heated water will be returned to the storage tank.

The storage tank has natural freeze protection, in that it is located sub-grade and well insulated, so the need for antifreeze and heat exchange components for the radiant floor districution system is eliminated. The mechanical room is located in the same space as the storage tank to allow more useable floor space in the new structure.

From the storage tank, the solar heated water is circulated through and "in-slab" radiant heat distribution system. This material is an EPDM extrustion formed into a four(4) tube mat configuration that is laid 12" apart, beneath the concrete slab. This allows the use of water at a lower temperature due to the increased radiating surface, which also increases the efficiency of the collector array by allowing them to operate at a lower inlet temperature. Collector heated water in turn heats the concrete slab which radiated the heat into the building. The water from the slab is returned to the storage tank, where it is routed back through the collector to be heated again.

If the temperature of the storage tank falls below the useful heating temperature (75°), the temperature sensors will instruct the circulating pumps to stop running. When the interior of the building reaches the predetermined minimum temperature level (58°), the sensors will instruct the back-up instantaneous water heater to activate and circulate hot water through the in-slab radiant material in the floor.

In order to supply heat to the existing shop a heat exchanger was placed in the present forced air furnace. The water is pumped from the storage tank through the radiator type heat exchanger then back to the storage tank. When additional heat is requested in the old addition a special thermostat is turned on. It automatically checks the temperature of the solar system, if warm enough the heating system will function without kicking on the gas furnace. If not warm enough it will resort back to the gas furnace.

A second heat exchanger is used to preheat the domestic hot water before entering into the hot water furnace.

The system works resembly well. Being completed late in the winter did not allow us to get any accurate analysis. However some problems did arise which need to be discussed. Lets briefly take a portion of the entire system.

Appendix 1 provides technical data regarding the Solar King Collectors. No problems have been encountered with them or their function. Appendix 4, pages 1,2 & 3 provides installation information. Appendix 5, the pictures give you a closer viwe point.

Appendix 1 thru 5 provide technical and visual looks at the radiant floor heating system. This system is very comportable as a source of heat. A few remarks will be made later in this section as to problem areas.

As far as the storage tank, other than leaking problems seems to be serving its purpose. The sub contractors who installed the tank failed to seal it correctly therefore causing priming problems.

The school district at this point is very pleased with the outcome of the system. It finally seems to be functioning quite well.

The following remarks were made by the solar consultants as they viewed problems and outcomes.

Problem areas:

1. Concrete tank leakage.
2. Piping out the top of tank rather than the sides can cause priming problems due to lack of head pressure on inlet side of pump.
3. Positive pressure needs to be applied to both inlet ports of the mixing valve to obtain a steady output temperature-radiant floor pump was moved to the tank side of the valve thereby providing positive pressure from the tank while the boiler pump supplies positive pressure from the boiler side.

4. Boiler was originally designed to be below solar tank water level-contractor made no provision for venting boiler from the mechanical room - the boiler was mounted above the solar tank on the main floor causing priming problems. Once the boiler was moved down to its proper location the priming problem was eliminated.
5. The return line from the collector coop was placed too close to the inlet line for the radiant floor loop. This allowed air being forced through the collector loop on the start-up, as the control called for the collector loop to come on, to be sucked into the inlet of the radiant floor loop causing the pump to vacitate seperation of these two lines solved this problem.
6. The original design required a long trench the length of the building for the radiant tube headers. It is now known that short headers in a central location with the radiant roll fanning out will work equally as well and reduce construction costs.
7. The school district would like to add that it would be best to insulate all exposed pipe with the covered insulation before fastening to the wall. A more professional job could have been done.

Recommend:

On radiant heat systems where exact temperatures are not required, such as a shop application, outdoor reset thermostats may not be required. The use of a mechnical mixing valve for a fixed water temperature and a thermostat directly linked to the circulation pump may be adequate.

Monitoring System

Monitoring of the System is accomplished by an Independant Energy Inc. C-100 differential controls which is capable of monitoring six seperate temperature locations by means of a digital readout panel. They are: 1) collector temperature, 2) storage tank temperature, 3) floor temperature, 4) air temperature of the unit space heater in the existing building, 5) the inside building temperature, 6) the outside air temperature.

in addition we are keeping utility usage records each month so that we can compare actual utility cost, with the active system, and the estimated utilities cost of this building without the solar participation in the heat load. In addition, the back-up system could run for a month before the solar system is activated, to get an accurate reference point upon which to compare actual utility savings.

Students are becoming involved in the monitoring process by compiling and maintaining accurate records in regards to the solar system participation in the annual heat load of the two buildings. This information will be made available to the public and especially other vocational programs in the state.

Because the project was not completed until late winter and into early spring of 1983 no accurate records will be available until 1984. The Department of Natural Resources plans to install an apple computer to compile and monitor pertenant information.

Fan Coil Circuit

A low voltage thermostat shall control the individual zone circulating pump and fan in each fan coil circuit to maintain the set space temperature. (see schematic)

Radiant Slab

An outdoor reset temperature controller shall operate a three-way valve to vary system water temperature from 75°F to 103°F as temperature drops from 60°F to -30°F. A second three-way valve will then allow boiler water to mix and maintain the required supply temperature. Pump shall not operate when outdoor temperature exceeds 60°F.

Solar Collector Loop

When the DTT-80T temperature differential controller senses higher temperatures in the collectors than in the bottom of the storage tank it will turn on the circulator pumps. The flow switch on the down side of the collector loop will sense flow and interrupt power to one of the pumps (P2) in series. As collector temperature drops close to storage temperature the DTT-80T will turn off circulator pumps (P2).

An aquastat set to open at 60°F on temperature drop acts as a fail safe device to interrupt the pump curcuit should the controller fail to shut off and contunue to pump heat to the outside when solar is not available.

Inserted in the storage tank is a heat exchanger loop that is tied into two existing forced air unit heaters that are located in the present shop building. These heat exchangers are rated at 57,000 BTU's/hour with 120° incoming water. When there is a demand for heat in this area and there is heat available in the storage tank, a pump will be activated to circulate hot water through these heat exchangers and the resulting heat will be distributed by the existing fan assembly. (see figure 3)

In addition to the above stated functions, we are also heating water for a 55 gallon domestic hot water tank. This tank has a back-up heating element for use when the water in the storage is not hot enough. When this situation occurs the back-up element will be activated to bring the water temperature to useable levels. The Solar System will be, in that situation, used to preheat the water coming into the domestic hot water tank thereby reducing the load on the heating element. When there is enough heat in the storage tank the domestic hot water will be heated through the storage tank heat exchanger. (see figure 4)

The system for this project is a drain back solar system. In a system of this type, water from the storage tank is circulated directly through the collectors and back to the storage tank. This arrangement eliminates the need for a heat exchanger in the collector loop and in so doing increases the efficiency of the system. By eliminating one generation of heat exchange we eliminate the corresponding loss of efficiency.

The system will finction without anti-freeze solution in the collector loop there fore freeze protection is provided. When the temperature of the water in the collectors reaches a predetermined minimum level, the circulateing pumps will shut down and the water in the collectors will drain back in the storage tank. When the temperature in the collectors reaches a level higher than the temperature of the storage tank (higher than the freezing point) the pumps will begin circulating water through the collectors.

If the electricity fails, the pumps will be inoperative and the system again will drain down into the storage tank until the power supply is resumed.

If the differential sensors fail to function the system must radiate all the heat in the storage tank out through the collectors before the system will freeze. In this instance, the system can be manually shut down and the water will be drained into the storage tank.

CIRCULATION PATTERN FOR
EXISTING UNIT HEATERS

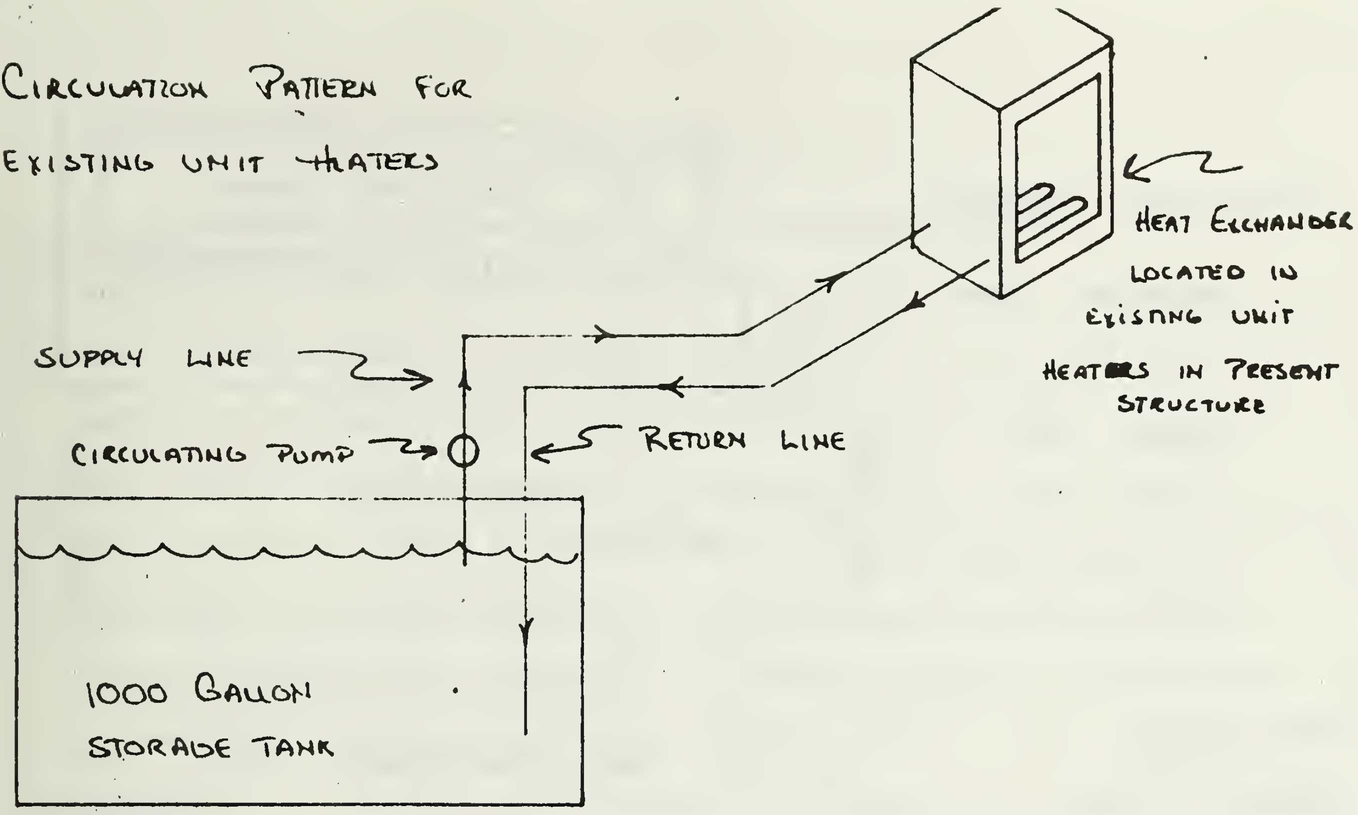


FIGURE 3 (NOT TO SCALE)

CIRCULATION PATTERN
FOR DOMESTIC HOT WATER SYSTEM

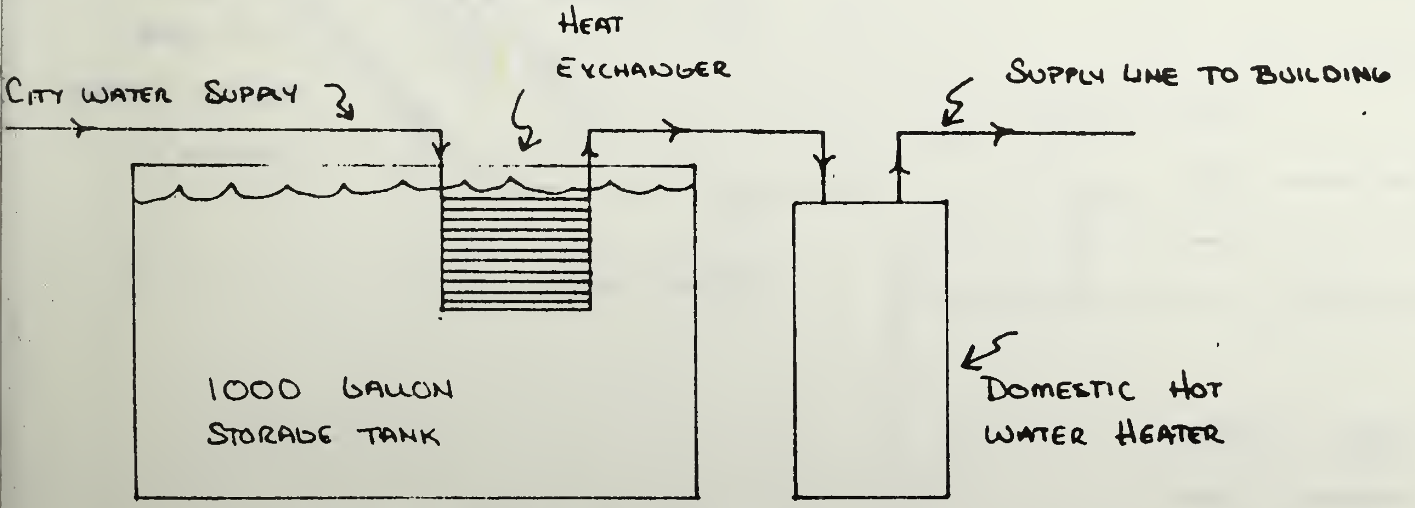


FIGURE 4 (NOT TO SCALE)

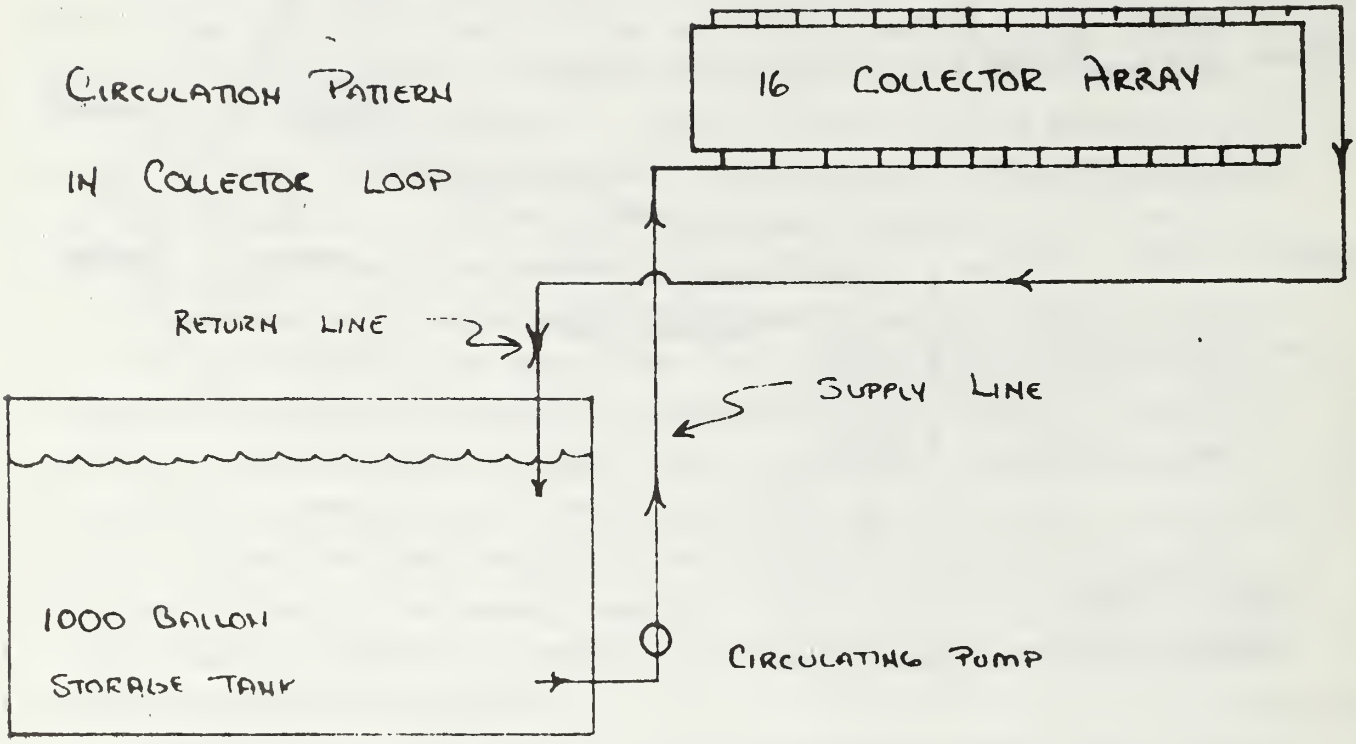


FIGURE 1 (NOT TO SCALE)

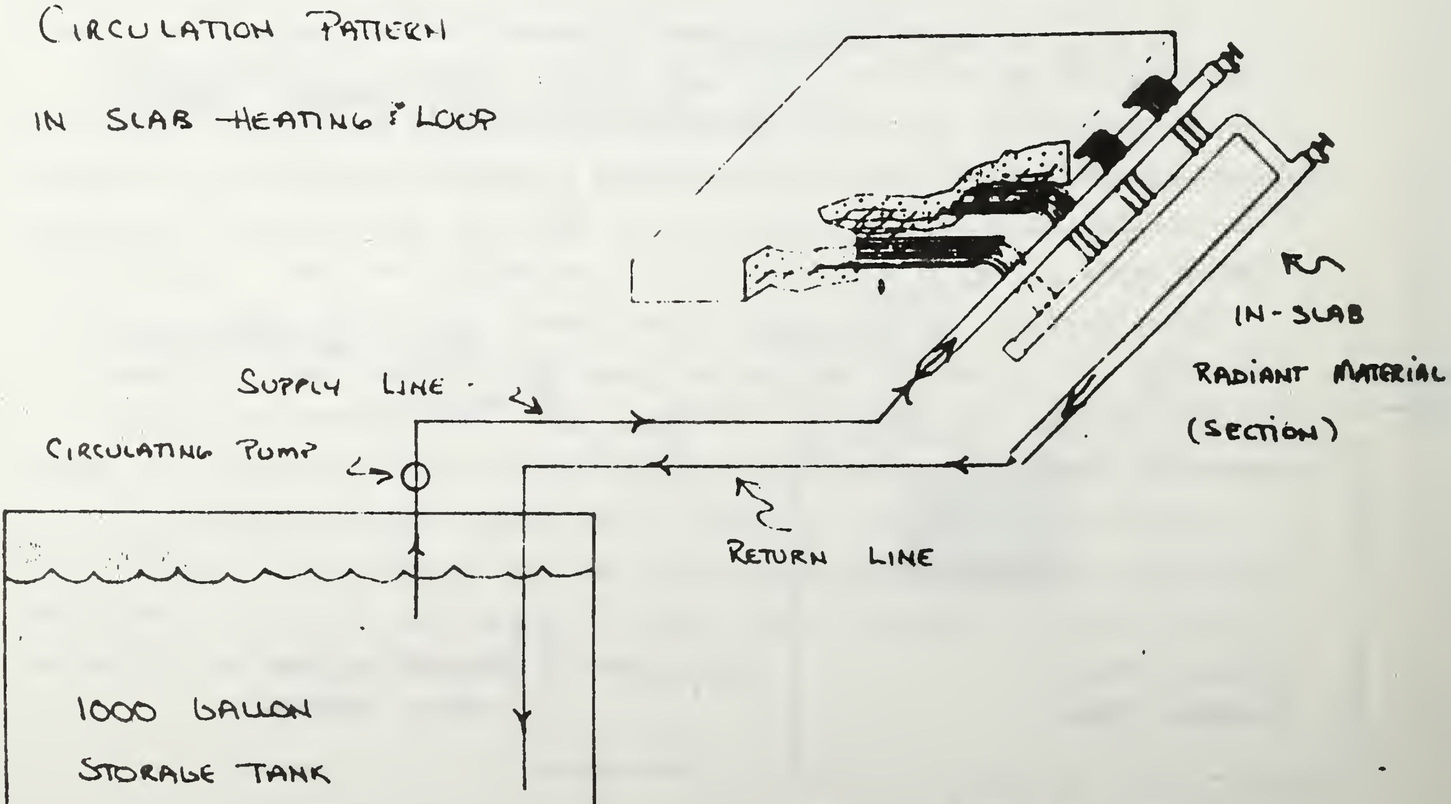


FIGURE 2 (NOT TO SCALE)

Energy Analysis

To calculate the annual heat load for a new building a heat loss must be figured in order to correctly size a solar system. Attached is a heat loss calculation based on the number of degree days in a year and careful analysis of the heat retention characteristics of this building. (figure 5) Also included is a sheet outlining the annual heat load than a building using conventional forced air resistance heat. With a forced air system the highest heat concentration will be at the ceiling where the heat loss through the ceiling will be greater. In contrast, a radiant in-slab system has the highest heat concentration at the floor where heat loss is minimal. In addition, the back-up system for an in-slab system will require less energy than will a forced air back-up.

When applied to the new addition and the present structure the solar system will provide on the average 90,000,000 BTU's toward the annual heat load of 195,135,600 BTU's. (figure 6)

SOLAR PARTICIPATION CHARTS

SOLAR FRACTION

(APPLIED TO ADDITON ONLY)

80,635,600	BTU Seasonal Heating Required	
+8,000,000	Btu Seasonal Domestic Hot Water Required	
88,635,600	BTU Heating and Hot water Requirement	
(1)68,000,000	BTU Supplied by the Solar System	77%
20,635,600	BTU Backup Heating Required	

SOLAR FRACTION

(APPLIED TO ADDITION AND ADJOINING BUILDING)

80,635,600	BTU Requirement for new addition	
106,500,000	BTU Estimated requirement for adjoining building	
195,135,600	BTU Total requirement for both buildings	
(2)90,000,000	BTU Suplied by the Solar System	46%
105.135,600	BTU Backup Heating Requirement	

---

(1) The Solar Collectors will supply 4.25mm BTU's each if heating only the new addition: 4.25mm/BTU x 16 Collectors = 68mm BTU's/year

(2) The same Solar Collectors will supply 5.625mm BTU's each if heating the new addition and the adjoining building
5.625mm/BTU x 16 Collectors = 90mm BTU's/year

Figure 7

BUILDING HEAT LOSS: @ 80°F TEMPERATURE DIFFERENTIAL

CONDUCTIVE LOSS: (60°F INSIDE, -20°F OUTSIDE)

STRUCTURE PART	U-FACTOR	ΔT 80°	AREA S.F.	BTU/HR LOSS
Roof	.026	"	2592	5391
Walls	.220	"	2395	42152
Foundation	.091	"	624	4534
Overhead Door	.143	"	224	2563
Entry Door	.125	"	21	210
Vent	1.500	"	12	1440
		TOTAL CONDUCTIVE HEAT LOSS		56299
		AIR INFILTRATION, STRUCTURE		7912
		AIR INFILTRATION, OCCUPANT		31750
		TOTAL HEAT LOSS		95961 BTU/hr

DEGREE DAY YEAR/ PER INTERIOR TEMPERTURE

MONTH	@65°F	@58°F	@55°F
JANUARY	1336	1136	1036
FEBRUARY	1056	835	753
MARCH	1004	804	704
APRIL	612	412	312
MAY	333	153	91
JUNE	131	55	32
JULY	10	0	0
AUGUST	15	0	0
SEPTEMBER	221	95	55
OCTOBER	487	307	242
NOVEMBER	879	679	579
DECEMBER	1184	984	784
TOTAL	7265	5460	4588

(FIGURE 5)

ANNUAL HEATING REQUIREMENT

96,000 BTU LOSS @ 80° ΔT
÷80 TEMPERATURE DIFFERENTIAL
1,200 BTU LOSS/HR. @ 1° TEMPERATURE DIFFERENTIAL
x24 HOURS PER DAY
28,800 BTU LOSS/DAY @ 1° TEMPERATURE DIFFERENTIAL

ANNUAL HEATING REQUIRED WITH UNIT SPACE HEATERS
NO SOLAR PARTICIPATION (AVERAGE 58°F INDOOR TEMP.)
→ 28,800 BTU LOSS/DAY @ 1° TEMPERATURE DIFFERENTIAL
x5,460 DEGREE DAY YEAR @ 58° INSIDE TEMPERATURE
157,248,000 BTU PER YEAR
-23,970,800 BTU PER YEAR / SUN TEMPERING & INTERNAL GAIN
133,277,200 SEASONAL HEATING REQUIREMENT / BTU'S

ANNUAL HEATING REQUIRED WITH RADIANT FLOOR SLAB
AND ACTIVE SOLAR SYSTEM (AVERAGE 55°F INDOOR TEMP.)
→ 28,800 BTU LOSS / DAY @ 1° TEMPERATURE DIFFERENTIAL
x4,588 DEGREE DAY YEAR @ 55° INSIDE TEMPERATURE
104,606,400 BTU PER YEAR
-23,970,800 BTU PER YEAR / SUN TEMPERING & INTERNAL GAIN
80,635,600 SEASONAL HEATING REQUIREMENT / BTU'S

FIGURE 6

Ecomonic Analysis

The following is a breakdown of the cost of the proposed system and the expected payback rate.

These figures are based on the following assumptions.

1) the heating load, and therefore, the utility costs, are based on the premise that a conventional heating system would require much more energy than the proposed solar system
2) utility costs can be expected to increase, due to inflation an average of 20% per year. In this area natural gas prices have increased 75% since January.
3) the efficiency of the system will be increased by supplying heat to the existing building.
4) natural gas fired heating systems average 75% efficient.
5) natural gas deregulation will be a reality by at least 1985.

Based on the above conditions and the following calculations we anticipate the system will pay back in 10 - 11 years.

Solar System Cost Includes:

Space heating for new addition
Space heating for existing building
Hot water heating for new addition

Solar equipment	$16,620.67
Build & Install 1000 gallon storage tank	700.00
Collector support frame & installation	780.00
Collector manifold material	360.00
Radiant roll installation	215.00
Plumbing cost	3500.00
Electrical cost	320.00
	22,495.67
Solar design & engineer's fee	500.00
Installation and labor cost	4,000.00
	26,995.67
Less standard heating system	1,270.00
Solar system cost	25,725.67

Economic Analysis continued

133mm BTU heating required with out solar system
-21mm BTU heating required for back up heat with solar system
112 mm BTU per year savings on addition
+22 mm BTU from solar if adjacent building is also solar heated
134 mm BTU savings with solar
70% gas burner efficiency
191 mm BTU natural gas input
$3.78 cost per mm BTU for natural gas
$722.00 savings at present gas price

Utility cost savings @ 20% yearly increase

1 1982 866.40 =
2 1983 1039.68 = 1906.08
3 1984 1247.62 = 3153.70
4 1985 1497.14 = 4650.84
5 1986 1796.57 = 6447.41
6 1987 2155.88 = 8603.29
7 1988 2587.06 = 11190.35
8 1989 3104.47 = 14294.82
9 1990 3725.36 = 18020.18
10 1991 4470.43 = 22490.61

Work Schedule

The work schedule went as planned in the Milestone Chart. The only problems that were encountered was having to wait on the general contractor. He was extremely slow. The architect, because of his screw ups, caused problems with the boiler. When located where it was designed, functioned properly. Recommendations are to get a competant architect and general contractor.

Budget

Following is the complete budget that solar works used to calculate the entire cost of the project. Along with this is a supplies, materials and equipment inventory.

BID SHEET
SOLAR EQUIPMENT
HYDRONIC SPACE HTG. SYSTEM

FOR: PARK CITY HIGH SCHOOL DATE: 3·29·82

ADDRESS: FFA BUILDING ADDITION

QTY.	CODE	P/N	DESCRIPTION	PRICE EA.	PRICE MULT.
12/16	/104	S6·15	COLLECTOR	535.00	8560.00
64	208	SK·33B	MTG. BRACKETS, COLLECTOR	.97	62.08
16	205	SK-22	HOSE, COLLECTOR-MANIFOLD	8.30	132.80
64	206	5X445	CLAMPS, HOSE	.84	53.76
OPTION 48	212	SW·MC·100	MANIFOLD COVER TOP ONLY	3.50	OPTIONAL 168.00
1	213	SW·ME·LH1	END, L.H. MANIFOLD COVER		4.00
1	214	SW·ME·RH1	END, R.H. MANIFOLD COVER		4.00
OPTION 5	215	SW·MS·100	SPLICE, MANIFOLD COVER	1.50	7.50
2	714	SK·12	VACUUM RELIEF VALVE	18.80	37.60
2	717	SW·SV·100	SHIELD, VAC. REL. VALVE	10.00	20.00
3	413	UP·26·64F	PUMP, COLLECTOR 10G.P.M/32 F.H.	120.56	361.68
2	412	UPS·20·42F	PUMP, HEAT DIST.	88.69	177.38
			PUMP, HEAT DIST.		
2	426	51.9603	PUMP FLANGE 1¼"	5.35	10.70
3	425	51.9602	PUMP FLANGE 1"	5.35	16.05
1	618	DTT·80T	CONTROL, DELTA T COLLECTOR		228.43
			CONTROL, DELTA T		
1	610	2E399	AQUASTAT, COLLECTOR		39.50
1	610	"	AQUASTAT, HEATING		39.50
1			SWITCH, CONTROL, BOILER		20.00
			VALVE, CONTROL		
3	613	2E156	THERMOSTAT	12.91	38.73
3	630	4X744	TRANSFORMER	8.06	24.18
3	609	6X562	RELAY	13.89	41.67
360	310	40 MILL	STORAGE TANK (18'×20') 1028 GAL.	1.65	594.00
1	902	SK-32	WATER TREATMENT (5 GAL.)		125.00
1		120'×3/4"	HEAT EXCHANGER, D.H.W.		120.00
2	811	SHW·234T	COIL, AIR-WATER (20"×25"/2 ROW	257.14	514.28
4	ROLLS	T-MB	1000' 4 TUBE RADIANT ROLL	1070.00	4280.00
10	1"	HC-28	COPPER HEADER SET	70.50	705.00
			MISS SOLAROLL EQUIPMENT		27.50
8	716		PETES PLUGS	8.57	68.56
1	715	SK-38	TEMPERING VALVE		24.77
			FLOAT VALVE ASSEMBLY		25.00
1		SD·40	(96,000 B.T.U.) BOILER		480.00
			TOTAL SYSTEM EQUIPMENT COST		17,011.67

BID SHEET
SOLAR INSTALLED PRICE
HYDRONIC SPACE HTG. SYSTEM

FOR: Park City High School DATE: 3/29/82

ADDRESS: FFA Building Addition

DESCRIPTION	6/24/82	PRICE
COLLECTORS DORMER MTL. & LABOR	O.K.	400.00
SET COLLECTORS	O.K.	320.00
PLUMBING, MTL. & LABOR SOLAR & SLAB	3275.00	2700.00
INSULATE PIPES	O.K.	450.00
INSTALL MANIFOLD COVERS	90.00	70.00
STORAGE TANK MTL. LABOR: SIZE	840.00	700.00
INSTALL HEATING COIL	1464.00	1200.00
WIRE CONTROLS LOW VOLTAGE ONLY	412.00	320.00
START UP & CHECK SYSTEM	O.K.	150.00
INSTALL RADIANT ROLL	625.00	500.00
TOTAL OF ABOVE	8026.00	6810.00
OVERHEAD	401.00	—
TOTAL OF ABOVE	8427.00	
SALES COMMISSION		—
TOTAL SYSTEM INSTALLATION COST	8427.00	6810.00
SOLAR EQUIPMENT COST	16,800.41	17,011.67
SOLAR DESIGN & ENGINEER'S FEE	500.00	500.00
TOTAL SOLAR SYSTEM INSTALLED PRICE	25,727.41	24,321.67

BID SHEET
SOLAR EQUIPMENT
HYDRONIC SPACE HTG. SYSTEM

FOR: PARK CITY HIGH SCHOOL DATE: 6-24-82

ADDRESS: FFA BUILDING ADDITION

QTY.	CODE	P/N	DESCRIPTION	PRICE EA.	PRICE MULT.
12	109	SS-12	COLLECTOR (4' x 8')	700.00	8400.00
48	208	SK-33B	MTG. BRACKETS, COLLECTOR	.97	46.56
12	205	SK-22	HOSE, COLLECTOR-MANIFOLD	8.30	99.60
48	206	5X445	CLAMPS, HOSE	.84	40.32
~~0~~			~~MANIFOLD COVER~~		
~~0~~			~~END, L.H. MANIFOLD COVER~~		
~~0~~			~~END, R.H. MANIFOLD COVER~~		
~~0~~			~~SPLICE, MANIFOLD COVER~~		
2	714	SK-12	VACUUM RELIEF VALVE	18.80	37.60
~~0~~			~~SHIELD, VAC. REL. VALVE~~		
1		SK-	PUMP, COLLECTOR		448.00
2	413	UP-26-64F	PUMP, HEAT DIST. COILS	120.56	241.12
1	412	UPS-20-42F	PUMP, HEAT DIST. RAD. ROLL		88.69
			PUMP FLANGE 1¼" & 1"	5.35	10.70
2	425	51.9602	PUMP FLANGE ¾"	5.35	10.70
1	618	DTT-80T	CONTROL, DELTA T COLLECTOR		228.43
			CONTROL, DELTA T		
1	610	2E399	AQUASTAT, COLLECTOR		39.50
1	610	"	AQUASTAT, HEATING		39.50
			~~VALVE, CONTROL~~		
			~~VALVE, CONTROL~~		
3	613	2E156	THERMOSTAT	12.91	38.73
3	630	4X744	TRANSFORMER	8.06	24.18
3	609	6X562	RELAY	13.89	41.67
1	CONC. CISTERN		STORAGE TANK 1200 GAL 495.00 SEPTIC TANK		660.00
2	GAL.		WATER TREATMENT		60.00
1		120' x ¾"	HEAT EXCHANGER, D.H.W.		120.00
2	811	SHW-2347	COIL, AIR-WATER (20" x 25") 2 ROW	257.14	514.28
4	ROLLS	T-MR	COIL, AIR-WATER RAD. ROLL	1070.00	4280.00
10	1"	HC-28	HEAT EXCHANGER, POOL COPPER	HDR. 70.50	705.00
			HEAT EXCHANGER, SPA MISC.		27.50
8	716		PETES PLUGS	8.57	68.56
1	715	SK-38	TEMPERING VALVE		24.77
			FLOAT VALVE ASSEMBLY		25.00
		SD-40	(96,000) B.T.U. BOILER		480.00

TOTAL SYSTEM EQUIPMENT COST 16,800.41

1 of 2

BID SHEET
SOLAR EQUIPMENT
HYDRONIC SPACE HTG. SYSTEM

FOR: PARK CITY HIGH SCHOOL DATE: DEC 8, 1982

ADDRESS: FFA BUILDING ADDITION - CURRENT PRICES

QTY.	CODE	P/N	DESCRIPTION	PRICE EA.	PRICE MULT.
12		SS-12	COLLECTOR	704.71	8456.52
12 Sets		SK-3310	MTG. BRACKETS, COLLECTOR	4.18	50.16
12'		SK-2221	HOSE, COLLECTOR-MANIFOLD	12.51	150.12
48		SK-2225	CLAMP, HOSE	1.53	73.44
			MANIFOLD COVER		
			END, L.H. MANIFOLD COVER		
			END, R.H. MANIFOLD COVER		
			SPLICE, MANIFOLD COVER		
			VACUUM RELIEF VALVE		
			[illegible], VAC. REL. VALVE		
2		UPS 26-64F	PUMP, COLLECTOR & flanges	164.29	328.58
1		UPS 20-42 f	PUMP, HEAT DIST. & flanges/Coil	134.29	134.29
1		UPS 20-42 f	PUMP, HEAT DIST. & flanges/SLAB		134.29
			PUMP FLANGE		
			PUMP FLANGE		
			CONTROL, DELTA T COLLECTOR		
			CONTROL, DELTA T		
SEE			AQUASTAT, COLLECTOR		
CONTROLS			AQUASTAT, HEATING		1662.88
			VALVE, CONTROL		
			VALVE, CONTROL		
			THERMOSTAT		
			TRANSFORMER		
			RELAY		
	CONC CISTERN		STORAGE TANK		660.00
2 GAL.			WATER TREATMENT		60.00
1			HEAT EXCHANGER, D.H.W.		160.00
1		SHW-3347	COIL, AIR-WATER		325.89
4	ROLLS	TMR	COIL, AIR-WATER RADIANT ROLL	1070.00	4280.00
10	HC-28	1" HEADERS	HEAT EXCHANGER, ~~[illegible]~~	70.50	705.00
			~~HEAT [illegible]~~ Misc. Equip		27.50
9	TM		PETES PLUGS		
1	SK-38		TEMPERING VALVE		24.77
1			FLOAT VALVE ASSEMBLY		25.00
1			BOILER		996.18

Cor

FOR: ______________________ DEC 8, 1982

ADDRESS: ______

QTY.	CODE	P/N	DESCRIPTION	PRICE EA.	PRICE MULT.
			CONTROLS		
1		DE-300W	DIPGITAL DISPLAY		220.46
1		C-30-15	CONTROL / I.E.		79.78
2		ST-1	I.E. SENSORS	9.01	18.02
1		DTT-600 ST	CONTROL / HELIOTROPE		108.88
1		R8239A	FAN CONTROL		35.71
1			TIME DELAY RELAY		42.60
2			PLUG RELAYS	16.57	23.09
1			FAN RELAY		25.93
1			AQUASTAT / HONEYWELL		27.00
1			AQUASTAT / RANCO		49.43
1			CONTROL BOX		125.00
1			BARBER COLMAN PACKAGE		
			1-VS-9313 VALVE		
			1-AT 8155 SET POINT ADJ.		
			1-CP-8102 CONTROL		
			1-TS-8501 } SENSORS		
			1-TS-8701		
			1-AT-215	810.24	810.24
1		4x744	24V TRANSFORMER		16.74
1			2 STAGE THERMOSTAT		80.00
			SUB TOTAL		1662.88

TOTAL SYSTEM EQUIPMENT COST ______

CUSTOMER ORDER

te of Order 6/24/82 Order Taken By L.D.

me PARK CITY HIGH SCHOOL Ship To PARK CITY HIGH SCHOOL

te Required ______ Cust. Order # ______ How Ship ______

ty	Part #	Description	Supplier	Inv	SW PO#	Shipped	Price	Freight	Bill
12	SK-0070	COLLECTOR, SS-12	SOLAR KING		4765	11/17/82			
12	SK-3310	FLUSH MTG. CUPS	" "	OFFICE		"			
12	SK-2221	SILICONE HOSE 1⅛" I.D.	" "		4765	"			
48	SK-2225	CLAMP 1⅛"	" "		4765	"			
2	UP-26-64F	PUMP, COLLECTOR	GRUNDFOS		4798	"			
2	UPS-20-42F	PUMP, HEAT DIST.	"		4798	"			
1		PUMP FLANGE 1¼"	"		"				
1		" " 1"	"		"	"			
1		" " ¾"	"		"	"			
1	DTT-600	CONTROL, DELTA-T	HELIOTROPE GEN.						
1	2E399	AQUASTAT, HEATING	W.W. GRAINGER						
1	1200 GAL.	SOLAR STORAGE TANK	McKEEVER			INSTALLED			
3	GALS.	WATER TREATMENT?							
1		D.H.W. HEAT EXCH'R.	ECO ENERGY, WYO.			5563			
1	SHW-3347	COIL, AIR-WATER (20×25)	MAGIC AIR			11/17/82			
4	T-MR	RADIANT ROLL	BIO-ENERGY			INSTALLED			
10	HC-28	1" HEADERS	" "			INSTALLED			
9	717	P/T PLUGS				11/17/82			
1	SK-38	TEMPERING VALVE	SOLAR KING			11/17/82			
1	~~GB~~ 150	150,000 B.T.U. BOILER	GALAXY			11/17/82			
1	V59313	MOTORIZED VALVE	TAC			11/17/82			
1	AT215	SENSOR WELL	TAC			11/17/82			
1	CP8102	2 INPUT CONTROLLER	TAC			12/7/82			
1	TS8501	SENSOR	TAC			12/7/82			
1	TS8201	SENSOR	TAC			12/7/82			
1	DER-300W	THERMOMETER	HELIOTROPE GEN.			12/7/82			

Conclusion Recommendations

As far as the school is concerned we are very ahppy with the entire solar project. Solar works had some problems getting the system to work correctly which was largely do to the architects mistakes and the contractor that installed the storage tank. We are looking forward to monitoring the system this entire winter. At this time we will have more accurate information in regard to its effectiveness. When compiled will be made a part of this report.

With the limited time we were able to observe the system we have been very pleased with it. We feel that it will serve our purpose and be very efficient.

Exhibits

The following is material that we were able to put together. Our copies were limited. The information should be very useful in analysing the entire system and observing what was done.

Exhibit One - Information dealing with the collectors that were used.

Exhibit Two - Information on the solar floor heating system.

Exhibit Three - Installation manual for radiant heating concrete slabs.

Exhibit Four - Pictures dealing with the project taken at various stages during the building project.

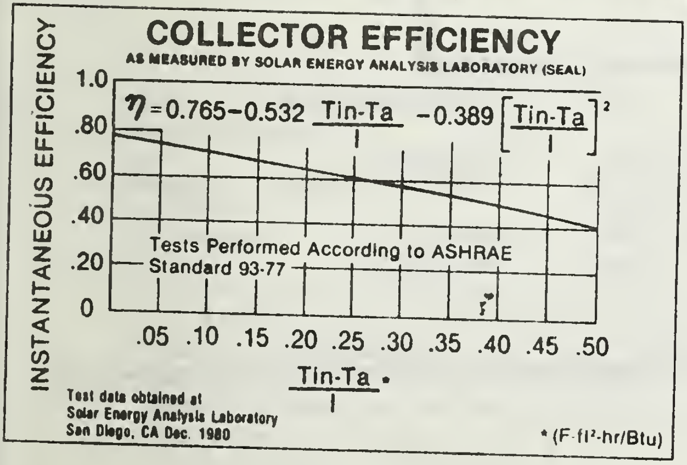
Exhibit Five - Blueprint of Project.

Decade 80

FLAT - PLATE SOLAR COLLECTOR

Solar King®

AMERICAN SOLAR KING / SG-15



$$\eta = 0.765 - 0.532\,\frac{T_{in}-T_a}{I} - 0.389\left[\frac{T_{in}-T_a}{I}\right]^2$$

Test data obtained at
Solar Energy Analysis Laboratory
San Diego, CA Dec. 1980

* (F-ft²-hr/Btu)

The American Solar King model SG - 15, Decade 80 is one of America's most efficient flat plate collectors.

Designed for maximum thermal performance, the Decade 80 is suitable for applications ranging from domestic hot water to solar air conditioning.

An exclusively designed, all copper, black - chrome absorber assures the high performance characteristics of the Decade 80. Solar King dedication to quality is evident throughout the collector design, right down to the "continuous" mounting flange extruded in the frame.

Feel free to contact American Solar King for clarification of specifications or independent test data on the Decade 80, the leader in flat plate collectors, from American Solar King . . . naturally!

AMERICAN SOLAR KING CORPORATION
7200 IMPERIAL DRIVE • P.O. DRAWER 7399 • WACO, TX 76710
817/776-3880
TELEX # 730916

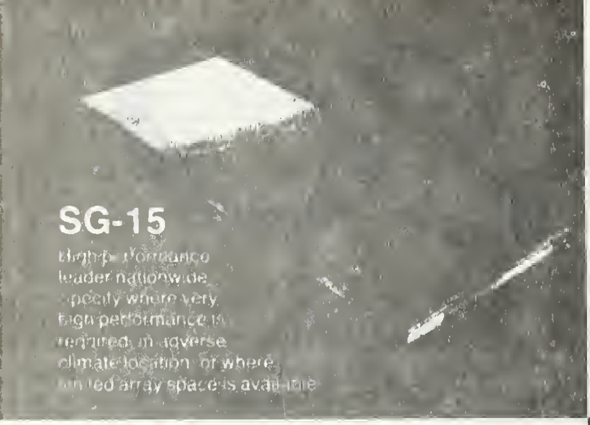
SPECIFICATIONS

TYPE OF COLLECTOR:
Flat plate, fluid circulating, integral flow, copper absorber.

OUTSIDE DIMENSIONS:	35.2" × 93.4" × 3.25"
GROSS AREA:	22.83 ft²
APERATURE AREA:	21.25 ft²
DRY WEIGHT:	110 pounds
FILLED WEIGHT:	115 pounds
COVER PLATE:	
Material	Tempered glass (less than .05% iron content)
Transmissivity	90.1%
Unit Configuration	Single Glaze
Density	2.51 g/m²
Coefficient of Linear Expansion	89.9 x 10⁷ (0 - 300 °C)
Wind Load	37 lb/ft²
Weight	1.3 lb/ft²
Thickness	0.125 ± .01 cm.
Impact Resistance	½ lb steel ball from 10 ft drop
ABSORBER PLATE:	
Material	99.9% copper
Selective Coating	* Black Chrome over nickle
Absorptivity	0.94
Emissivity	0.12
Max. Working Temperature	350 °F
Max. Fluid Pressure	100 PSI
Pressure Drop	1.5 PSI (3.45 ft H^20)
Flow Rate	14.7 lb/hr ft² (65 gpm)
Flow Pattern	Fully Interrupted
INSULATION:	
Minimum Value	R-15
COLLECTOR FRAME:	
Material	Extruded Aluminum
Thickness	.070"
Interior Coating	Anodized Bronze
Exterior Coating	Anodized Bronze
COLLECTOR BACK:	
Material	Aluminum
Thickness	.0159"
Interior Coating	Mill Finish
Exterior Coating	Black Paint

NOTE: The above data are nominal values.

*Chromonyx BCO#91



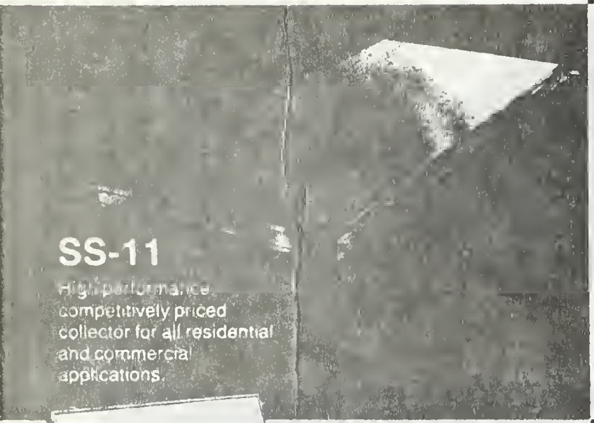
SG-15

High performance leader nationwide specify where very high performance is required in adverse climate location or where limited array space is available

SG-15

TYPE: Liquid
DIMENSIONS: 35.2" x 93.4" x 3.25"
GROSS AREA: 22.83 ft²
GLAZING: Low Iron Tempered Glass
ABSORBER PLATE: Copper

ABSORBER SURFACE: Black Chrome over nickel
INSULATION: R-15
COLLECTOR FRAME: Anodized Aluminum
MANIFOLD: External ⅝"
DRY WEIGHT: 110 lbs.



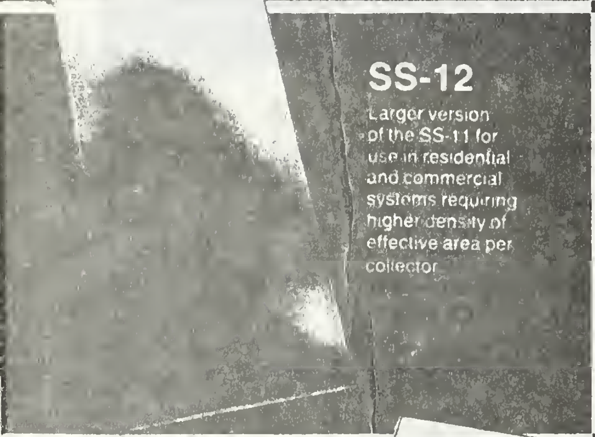
SS-11

High performance competitively priced collector for all residential and commercial applications.

SS-11

TYPE: Liquid
DIMENSIONS: 35.2" x 93.4" x 3.25"
GROSS AREA: 22.83 ft²
GLAZING: Low Iron Tempered Glass
ABSORBER PLATE: Copper

ABSORBER SURFACE: Black Chrome over nickel
INSULATION: R-15
COLLECTOR FRAME: Anodized Aluminum
MANIFOLD: Internal 1⅛"
DRY WEIGHT: 87.5 lbs.



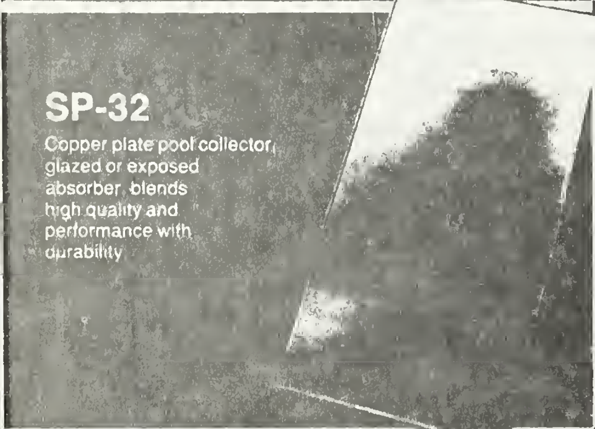
SS-12

Larger version of the SS-11 for use in residential and commercial systems requiring higher density of effective area per collector

SS-12

TYPE: Liquid
DIMENSIONS: 48.6" x 96.8" x 3.4"
GROSS AREA: 32.67 ft²
GLAZING: Low Iron Tempered Glass
ABSORBER PLATE: Copper

ABSORBER SURFACE: Black Chrome over nickel
INSULATION: R-15
COLLECTOR FRAME: Anodized Aluminum
MANIFOLD: Internal 1⅛"
DRY WEIGHT: 149 lbs.



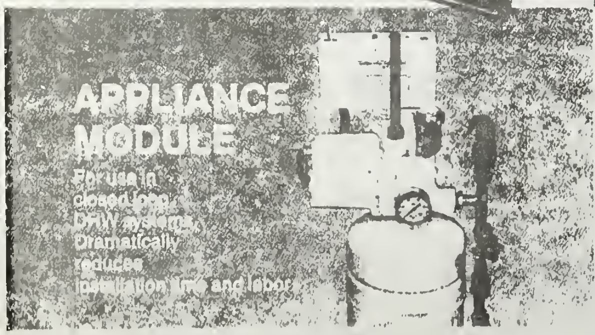
SP-32

Copper plate pool collector, glazed or exposed absorber, blends high quality and performance with durability

SP-32

TYPE: Liquid
DIMENSIONS: 48.6" x 96.8" x 3.4"
GROSS AREA: 32.67 ft²
GLAZING: Low Iron Tempered Glass
ABSORBER PLATE: Copper

ABSORBER SURFACE: High Temperature Black Paint
INSULATION: R-3.7
COLLECTOR FRAME: Anodized Aluminum
MANIFOLD: Internal 1½"
DRY WEIGHT: 142 lbs.



APPLIANCE MODULE

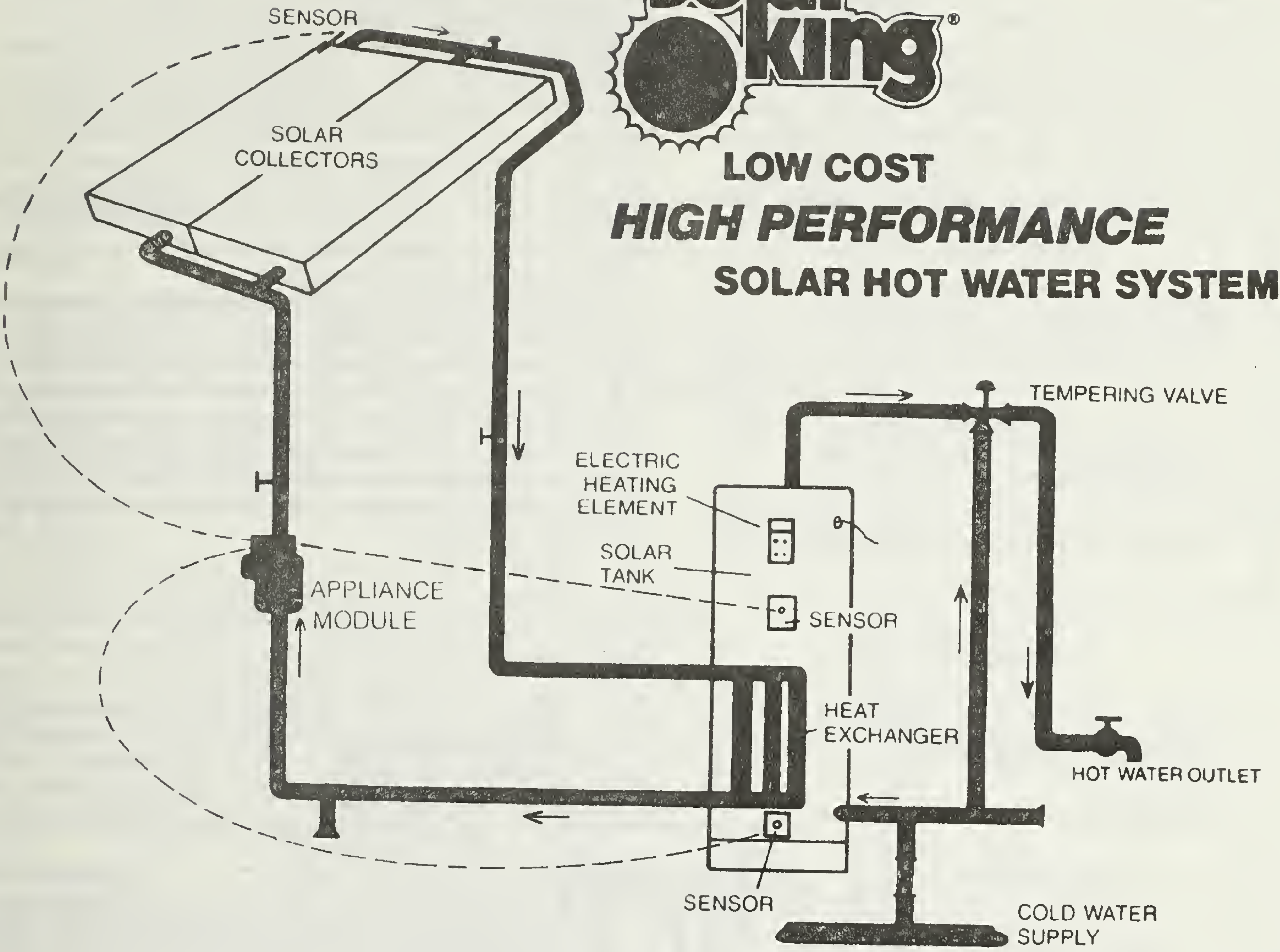
For use in closed loop DHW systems. Dramatically reduces installation time and labor

APPLIANCE MODULE

CONTROLLER: 120 VAC, 50/60 HZ, 6 Amps Resistive Maximum Turn-on 9° ± 3°, Turn-off 3.5° ± 1°
EXPANSION TANK: Maximum Working Pressure 75 PSI
CIRCULATOR: 1/25 HP, 3250 RPM, 115V. .75 Amp
PRESSURE RELIEF VALVE: Max. Working Pressure 75 PSI

Solar King®

LOW COST
HIGH PERFORMANCE
SOLAR HOT WATER SYSTEMS



The primary market for flat plate solar collectors lies in domestic and commercial hot water applications. In residential size, two or three collector, hot water systems American Solar King recommends a closed loop, non-toxic anti-freeze type configuration. In larger systems drain back freeze protection can be utilized.

American Solar King high performance collectors should be specified because *less* of them are required. In states such as California where specific array sizing methods are required based on performance ratings (TIPSE) Solar King® collectors out perform all others making American Solar King domestic and commercial hot water systems more economical to install than competing systems. Use of the Solar King Appliance Module further reduces installation costs.

SOLAR KING® serves the NATION and the WORLD!

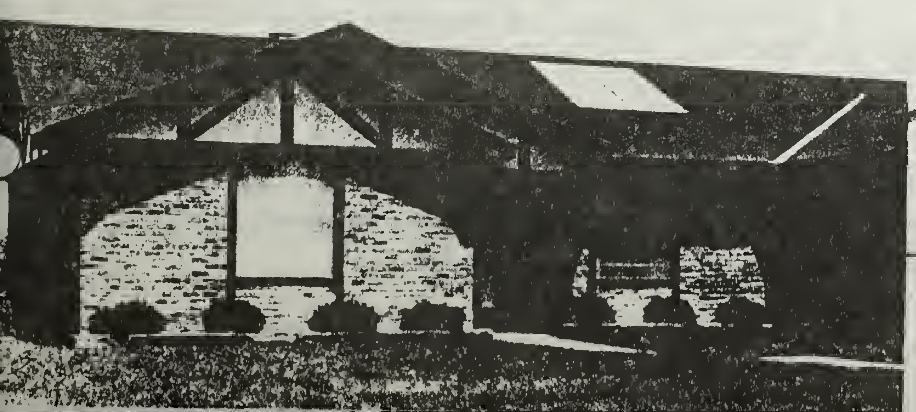


Exhibit 2

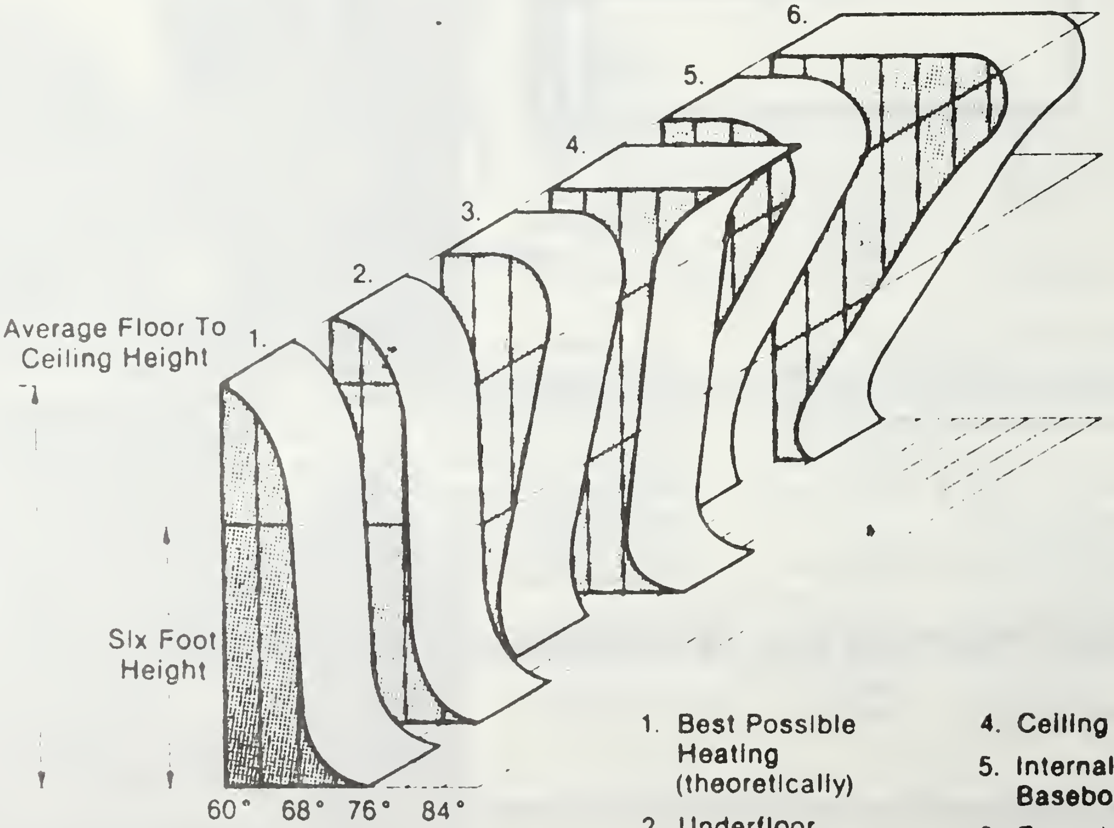
AN INTRODUCTION TO RADIANT HEATING

Radiant heating is a clean, comfortable form of heating with a tremendous potential to reduce fuel consumption in both residential and commercial buildings. Unfortunately, few people realize the tremendous advantages it offers over conventional methods of heat distribution. Conventional systems provide warmth by heating the air in a room. This type of heating leaves floors colder, creates convectional drafts and forms a wasteful concentration of heat near the ceiling. Natural humidity is baked out, and the circulation of air can draw off body heat.

Radiant heating, on the other hand, radiates an even, comfortable warmth to the objects, occupants and surfaces of a room, without first heating the air. Floors stay warm, floor-to-ceiling temperatures remain more nearly constant, body heat is retained and room air remains humid and feels fresher and more comfortable.

The heat-intensive elements of radiators and the high temperatures of hot air systems set up convectional drafts which can cause carbon particles to form around room dust. This is what produces the streaks of dirt on walls and furniture. Radiant heating operates at lower temperatures and requires less fuel. It will not cause convectional drafts or carbonization of dust. Lower operating temperatures and the radiant nature of under-the-floor heating combine to provide a more evenly distributed, energy-efficient system that closely approaches "ideal" heating. (See diagram on this page). A radiant system is also the perfect form of distribution for solar heating. It allows solar collectors to operate at lower, more efficient temperatures.

Radiant heating does not limit the architect or designer, because it is concealed beneath usable floor space. SolaRoll Radiant Heating, in particular, is highly versatile and easier to install than any other radiant heating system. Radiant heating is most commonly imbedded in concrete floors, but SolaRoll can also be fitted behind walls, in ceilings and under other types of floors. SolaRoll is ideal for new construction, and it will retrofit existing structures with ease.



1. Best Possible Heating (theoretically)
2. Underfloor Heating
3. External Wall Baseboard Radiators
4. Ceiling Heating
5. Internal Wall Baseboard Radiators
6. Forced Hot Air

Figure 1. Temperature Distribution In Rooms With Different Types Of Heating Systems

Exhibit 3

SOLAROLL®
INSTALLATION MANUAL FOR RADIANT HEATING CONCRETE SLABS

1. PREPARATION

SUBGRADE

The subgrade must be well drained and of adequate and uniform loadbearing nature. The "in-place density" of the subgrade soils should be at least the minimum required in the specifications. The bottom of an undrained granular base course must not be lower than the adjacent finished grade; otherwise the base course becomes a reservoir for water. Details of site preparation are given by ACI Committee 332 and the Building Research Advisory Board.

The subgrade must be free of frost before concrete placing begins. If the temperature inside a building where concrete is to be placed is below freezing it must be raised and maintained above 50°F (10°C) long enough to remove all frost from the subgrade.

The subgrade should be moist at the time of concreting. If necessary it should be dampened with water in advance of concreting, but there must be no free water standing on the subgrade nor should there be any muddy or soft spots when the concrete is placed.

VAPOR BARRIER

A vapor barrier should be placed over the subgrade. The most commonly used materials are polyethylene and polyvinyl, with a permeability of 0.03 perms or less. Careful workmanship is required to keep the vapor barrier from being punctured and to achieve a proper seal between individual strips. Overlap adjacent strips a minimum of 6 inches.

EDGE INSULATION

Two methods of edge insulation have proven economical and functional (See Figure 1.). Use a horizontal insulation at the edge of the slab, which extends at least 3 feet (1 m) in from the edge, or vertical insulation along the inside or outside of the footing down to the frost line. R-Values of the insulation should be chosen in accordance with Bio-Energy Systems Design Manual.

SLAB INSULATION

Insulation under the interior of the slab is advisable for certain installations. Two techniques are possible. The insulation can be placed on the vapor barrier, which will maintain the full strength of the slab, or the insulation can be installed inside the concrete. This is accomplished with two pours, one shortly after the other (See Concrete Pour Techniques, page 4). This technique creates a slab with a quicker response time, since the thermal mass of the radiant system is reduced.

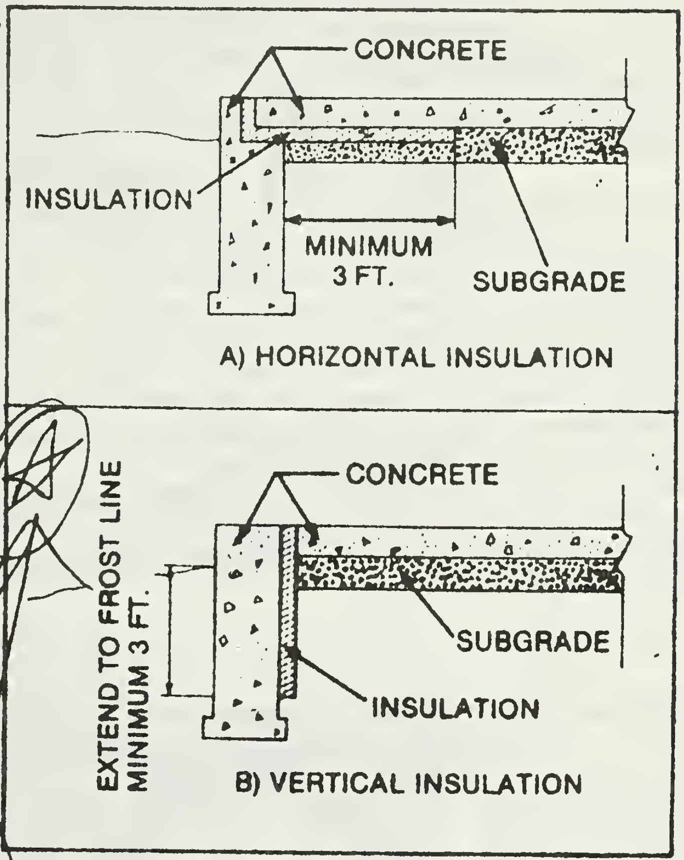


Figure 1. Recommended slab edge insulation detail.

STEEL REINFORCEMENT

Wire mesh should be placed on top of the Tube Mat to absorb the tensile forces created in the arch above the tubes when the slab is under stress.

For residential slabs on grade a welded wire fabric 6×6 - 10×10 (old designation) or 6×6 - W1.4×W1.4 (new designation) is usually sufficient. In other situations careful consideration has to be given to structural requirements. Refer to ACI Standard 439 2R-77 for detailed recommendations. Careful attention is required to avoid puncturing the Tube Mat with the jagged wire ends. All ends should be bent upwards before installing the wire mesh.

PRESSURE TESTING

The Tube Mat should be pressure tested prior to the pour, but after it is laid out and connected to the headers. The recommended test pressure is 30 psi (2.1 kg/cm²). Each header set should be isolated and con-

≤30psi/½hr. ε 97% H_2O

nected to a separate pressure gauge. The scale of the gauge should be in increments of 1 psi (0.05 kg/cm²) or less. The system should then be filled with water to more than 97% of its capacity and pressurized to 30 psi. Pressure should be maintained for at least ½ hr. If it drops less than 1.0 psi (exclusive of environmental effects) the test is complete. If there is a pressure loss inspect the top and the bottom of the Tube Mat for wet spots. Leaks can be easily detected and should be mended with the Quick-Splice Repair Kit™ according to the instructions included in each kit. Be sure to empty out the water or account for it if the working fluid will be a propylene-glycol mixture.

CONTROL JOINTS

Caulking in expansion joints

Control joints are formed, sawed, or tooled grooves in a concrete structure. They create a weakened plane and regulate the location of cracking resulting from the dimensional change of different parts of the structure. (See Figure 2). They are usually required when the slab area exceeds 20 ft by 20 ft (6 m × 6 m). A highly recommended technique is to use a crack inducer as manufactured by Schlegel Corp., Des Moines, Illinois 60018, (312) 299-7933. In all cases seal the joint to prevent possible penetration of any petroleum based products that might be used in the building. Petroleum based products adversely affect Tube Mat.

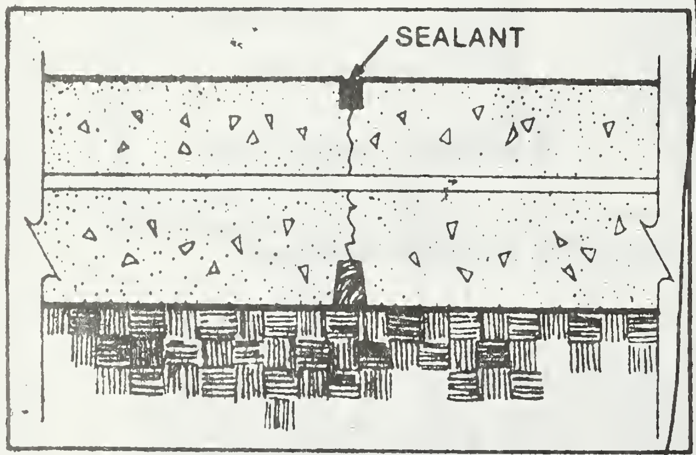


Figure 2. Control joint.

Or Expansion joints

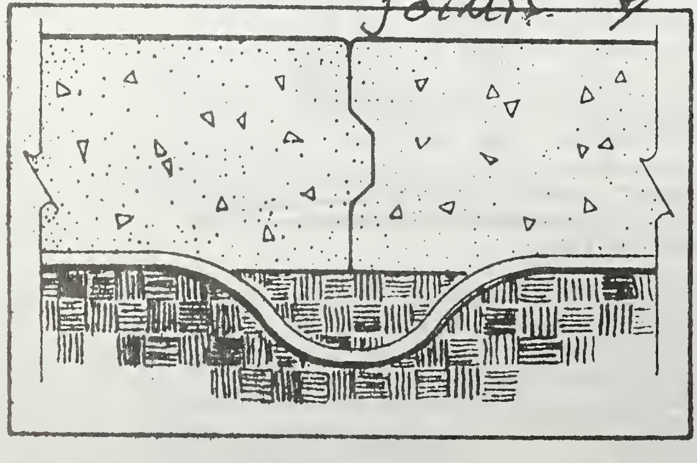


Figure 3. Construction joint (tongue and groove).

CONSTRUCTION JOINTS

Construction joints are lines where the edges of two successive placements of concrete meet, across which it is desirable to develop and maintain bond between the two concrete placements, and through which any reinforcement which may be present is not interrupted. Typically there are several days between placements. The Tube Mat should dip down at the construction joint and be positioned at the bottom of the concrete (See Figure 3). Make sure the tubes are not pinched. When using the cold joint or double pour technique (See Concrete Pour Techniques on page 4), you can accommodate three areas by pouring the middle area first.

EXPANSION JOINTS

Expansion joints are separations between adjoining parts of a concrete structure which is provided to allow small relative movements such as those caused by thermal changes to occur independently.

The Tube Mat should run underneath Expansion joints in the same way as underneath Construction joints, in order to protect it from the movements of the concrete.

2. POURING THE CONCRETE

CROSS SECTIONS

Three different slab cross-sections are possible, each offering specific advantages for different applications:

1) **Tube Mat at bottom of slab.** This construction maintains the full strength of the slab (See Figure 4). The Tube Mat is located directly on top of the insulation with the wire mesh on top of the mat. The slab provides thermal storage and its response time is fairly long. **Note:** The heat must pass through the full slab thickness with this construction. Consequently, higher fluid temperatures will be required.

2) **Tube Mat in the slab interior with the insulation at the bottom of the slab.** This construction is the most commonly used (See Figure 5). A smaller temperature difference is required to drive energy through the slab though the Tube Mat reduces the structural strength of the slab.

3) **Tube Mat and insulation in the interior of the slab.** This construction yields the shortest response time of the heating system and is widely used in Europe (See Figure 6). The insulation provides a thermal break inside the concrete, but reduces its strength somewhat.

Its use is limited to residential construction, where the load on the slab is minimal.

CONCRETE POUR TECHNIQUES

1) **Single pour, with the Tube Mat at the bottom of the slab.** If the Tube Mat is located at the bottom of the slab and the wire mesh positioned directly on top of it, the pour does not differ from any regular pour, except that care must be taken not to puncture the Tube Mat. Sharp instruments should not be used to shovel the con-

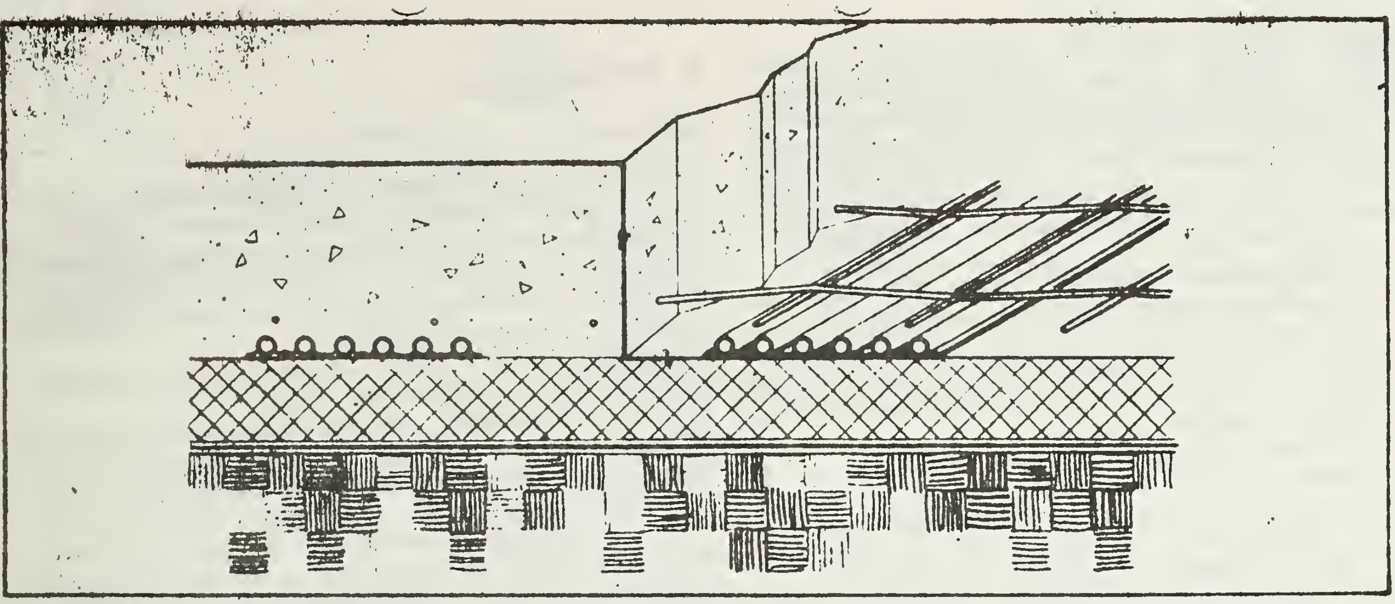


Figure 4. Cross section single pour.

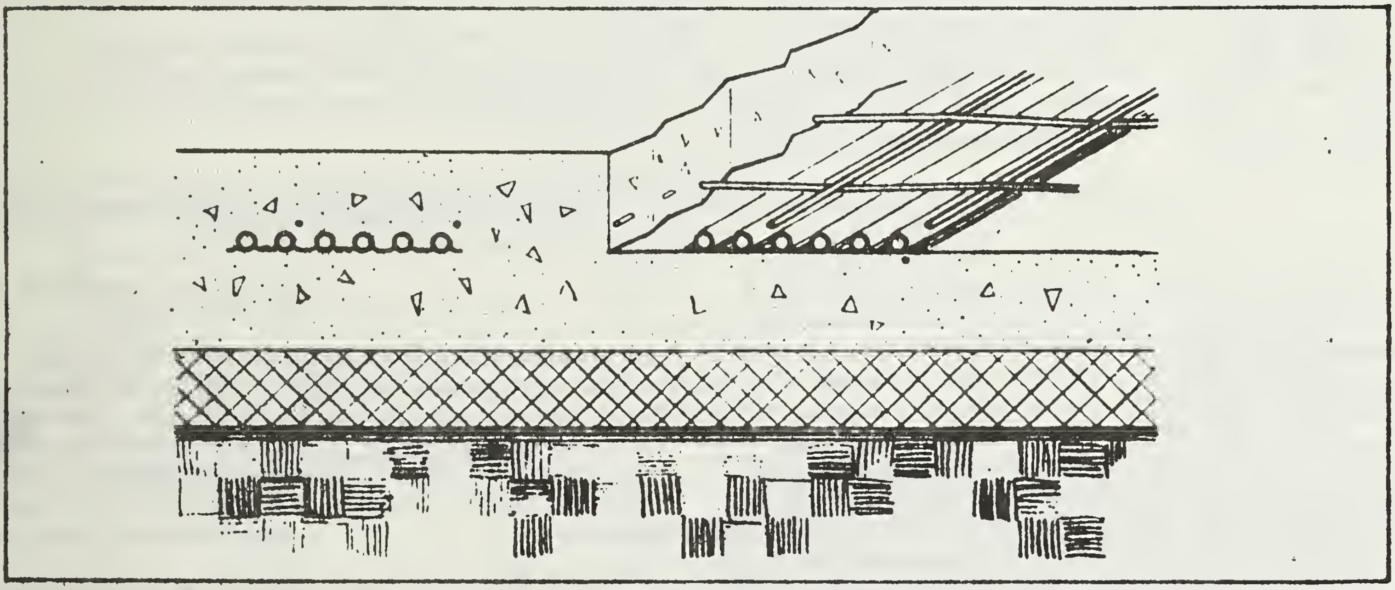


Figure 5. Cross section cold joint.

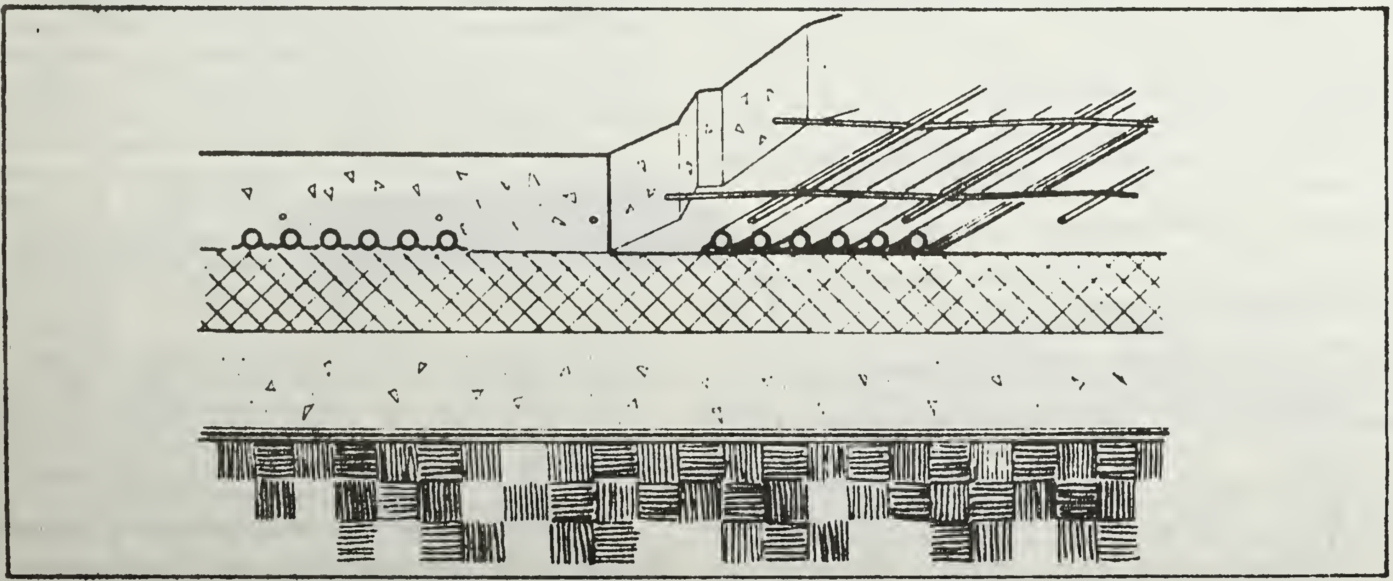


Figure 6. Cross section double pour.

crete or to lift the wire mesh. If the Tube Mat is punctured by mistake, the leak should be spliced without delay using the Quick-Splice Repair Kit™. The Tube Mat is not usually damaged by normal practice such as walking on the wire mesh with heavy boots or using wheel barrows or dragging concrete pumping hose across it. Reasonable care should be exercised, of course.

2) **Cold joint with the Tube Mat in the interior of the slab.** As the following paragraph will explain, there is no "cold joint" in the real sense of the term, neither is it a continuous pour. According to the Portland Cement Association a delay of a half hour or less does not affect the bond between the two pours.

If the tube mat is to be located in the interior of the slab (normally 2" (50 mm) down from the surface) to reduce the thermal resistance of the configuration, first pour a base equal to the desired thickness below the Tube Mat and screed very roughly. Immediately after this the Tube Mat and the wire mesh are placed on the soft surface. This can be done by putting them down separately one after the other, or by wiring the tube mat to the mesh every 2 feet (600 mm) using wire ties and placing the assembly on the concrete together. (Normally, workmen can walk on the wire without sinking substantially.) After this, the pour is continued and finished in the regular manner.

Changes in Tube Mat position during the completion of the pour depend upon the viscosity of the concrete and the amount of mechanical force used, but they are normally insignificant.

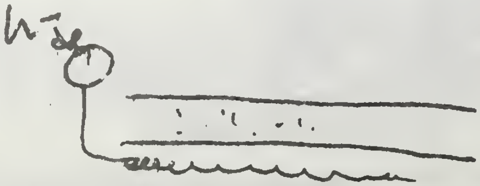
3) **Double pour, with the insulation and Tube Mat in the interior of the slab.** The initial pour is placed directly on the vapor barrier. It is screed very roughly. The insulation is immediately placed on top of the pour. After this, the Tube Mat and then the wire mesh are placed on the insulation. This can be done by putting them down separately one after the other, or by wiring the tube mat to the mesh every 2 feet using wire ties and by placing the entire assembly on the insulation. After this, the top layer is poured and screed in the regular manner. (The insulation will prevent the Tube Mat from changing depth within the slab.)

MAINTAIN PRESSURE DURING POUR

For all three pour techniques a pressure of 30 psi (2.1 kg/cm²) should be maintained in the Tube Mat during the pour. Any leaks which may be created during the pour can be detected and fixed immediately. The pressure will also prevent the tubes from collapsing.

HEADER PLACEMENT DURING POUR

During the pour the headers should be suspended above the surface of the concrete. Either attach them to a piece of wood or elevate them on poles. Or, isolate them from the concrete in a boxed-in well either in the wall or in the floor.



↖ Sol Roi

3. HYDRONICS

HEADERS

SolaRoll's unique counterflow fluid circulation provides a uniform temperature along the entire length of the Tube Mat. This helps eliminate the cold spots and the hot spots characteristic of single pipe systems. To achieve the counterflow the tubes are connected to the headers in an alternating pattern.

Balanced flow throughout all tubes is accomplished by one of the following two methods:

1) As with collectors, Reverse-Return Piping creates an equal pressure drop across each fluid path in the Tube Mat and, therefore, balances the flow (See Figure 7).

2) If the header length is less than 1/20 of the fluid path length in the Tube Mat and the velocity in the header is below 5 ft/sec, the Reverse-Return Piping may be omitted. Be careful, this technique saves pipe, but the situation must be examined carefully. When in doubt, use method 1.

The size of the copper headers should be selected according to the volume of flow passing through the header. Table 1 shows the recommended sizes.

Table 1. Header Sizes for Copper Headers

Volume of Flow (gpm)	0 - 11	11 - 22	22 - 42	42 - 63
Header Size (inches)	1	1½	2	2½

COMPONENTS

The balance of the system should include all components usually installed in a hydronic heating system, such as expansion tank, air vents, air scoop and an appropriately sized pump.

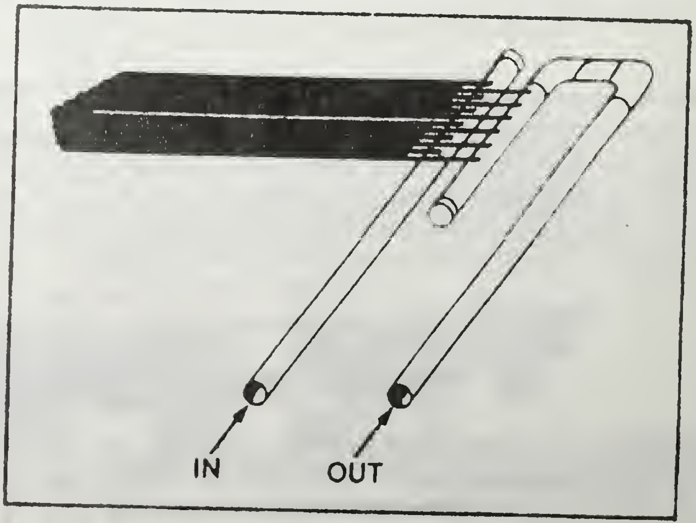


Figure 7. Reverse return plumbing for balanced flow.

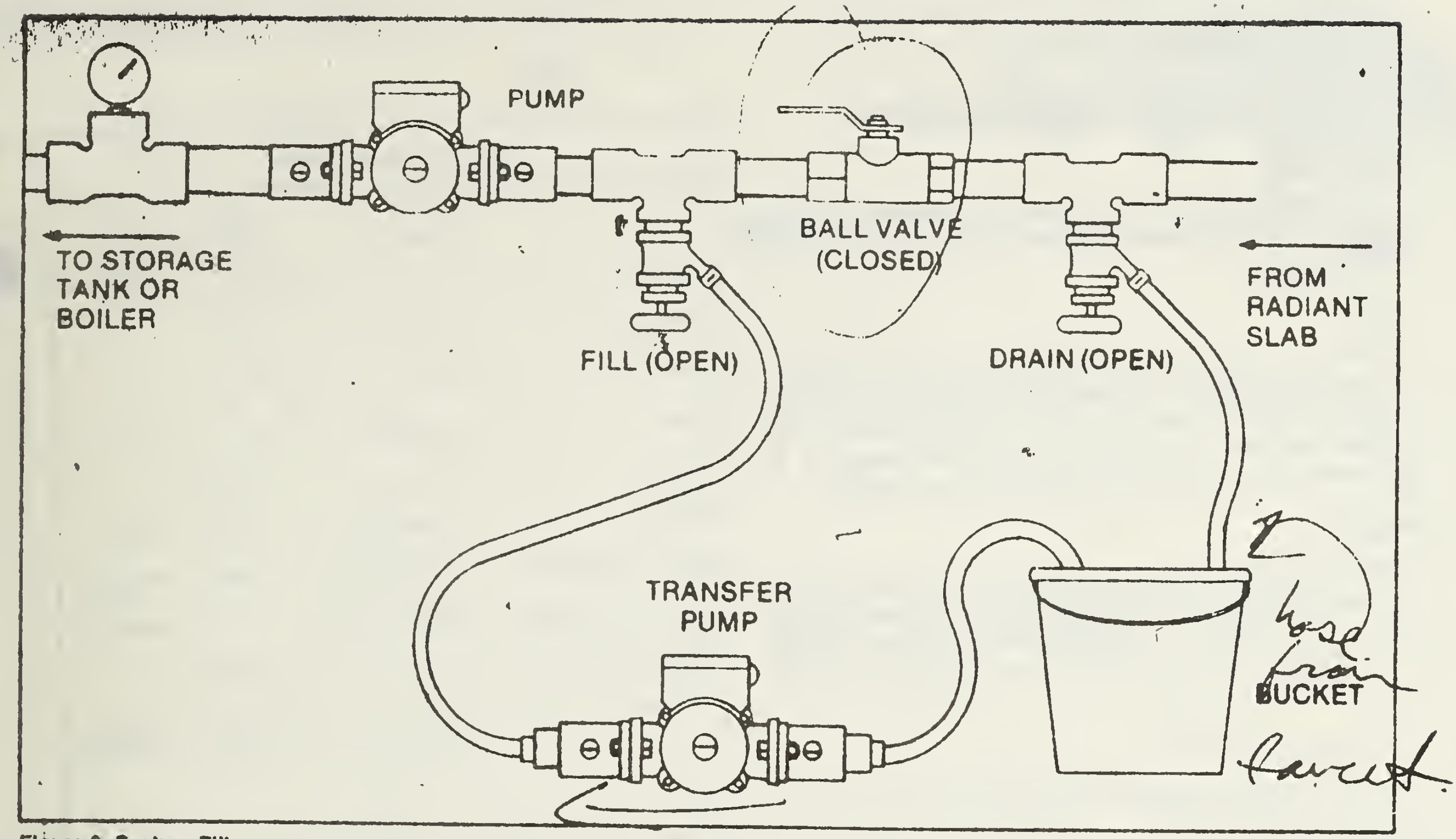


Figure 8. System Fill.

4. SYSTEM START-UP

Once the concrete is cured the Tube Mat should be pressure tested again to make sure the system is tight. In case of a leak the single leaking tube should be identified and isolated by either removing the tube and plugging the holes in the header or "short-circuiting" the loop with a short piece of Tube Mat. Tie a knot in the loop to prevent unwanted flow.

FLUSHING THE SYSTEM

l/100 ft²

Open both fill and drain valves and close the ball valve between them. Fill a large bucket with clean water. (Approximately one gallon per 100 sq. feet of floor area) Connect a small, self-priming pump to the fill valve with the pump suction line in the bucket. A hose from the potable water supply may be used to maintain the level in the bucket. Attach another hose to the system drain and direct it to a waste water drain.

Purge the system for 10 to 15 minutes. Remove and clean all strainer screens. The fluid which is discharged will contain construction debris, but will not be toxic otherwise.

The technique described above will assure that the Tube Mat is not overpressurized. If using water directly from the potable water supply to purge the system, a pressure regulating valve will be required. The maximum pressure should be set to 30 psi or less.

FILLING AND PRESSURIZING THE SYSTEM

Fill the system with heat transfer fluid. Use water or a propylene-glycol/water mixture only.

Propylene-Glycol To fill the system with a propylene-glycol/water mixture, repeat the flushing procedure with a bucket of heat transfer fluid (See Figure 8). Run the transfer pump for about 20 minutes to purge air from the system, recirculating the same fluid. Close the drain and open the ball valve.

Pressurize the system to the desired pressure, usually 1
12 to 20 psi (0.8 to 2.0 Kg/cm²). Close the fill valve. Shut
off the transfer pump. Cap and tag the fill and the drain 2
valve with fluid type, fill date and emergency pro- 3
cedures. Post this information on a wall chart by the circuit breaker for the system pump.

Water Use the procedure described for propylene-glycol. If you fill the system directly from the city water line use a pressure regulating valve to make sure the pressure in the radiant system does not exceed 30 psi

Do Not Connect Directly to City Water

SEASONING THE TUBE MAT

Before the radiant floor is put into operation, the Tube Mat should be seasoned so that thermal shocks will not have any negative impact.

Bring the temperature in the system up in steps of 20 °F (10 °C) per hour to the peak operating temperature (Ti in the Radiant Design Worksheet). Note: If Ti is above 180 °F (80 °C), consult Bio-Energy Systems

The system should be left in operation at peak temperature for a period of no less than two hours.

Following this procedure will ensure full protection of the Tube Mat against future severe temperature changes.

[illegible] AND MAINTENANCE

PRESSURE

The system should be operated at a pressure of 12 to 20 psi. At no time should the pressure on the Tube Mat exceed 30 psi.

FLUID

In case a propylene-glycol mixture is used as the heat transfer fluid, the pH, the reserve alkalinity and the concentration should be checked at manufacturer's suggested intervals. Normally, buffers will need to be replenished or the fluid replaced every two years.

PUMPS

Some circulator pumps are sealed and permanently lubricated, others are lubricated by the heat transfer fluid, and still others require periodic lubrication. Check the manufacturer's literature for recommended lubrication schedules, if any.

PRESSURE GAUGES

Check the system pressure periodically to see if it falls within the proper range.

PLUMBING

Inspect fittings, insulation, and seals once a year for visible leaks. If a leak appears, shut down the system immediately for repairs.

AIR VENTS

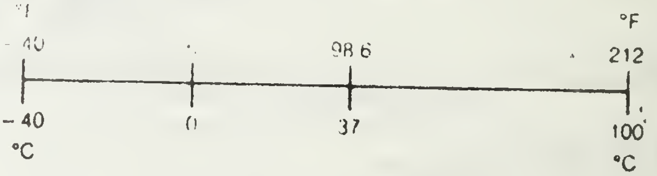
Check for clean floats and seals. An air vent will sputter audibly if any dirt or debris is caught in the mechanism. Caps should be checked to make sure that they are still loose enough to allow air out of the system. Screw caps tight by hand and then loosen them two turns. If the float mechanism becomes inoperative, the air vent must be replaced.

VALVES

Valves containing filters must be taken apart periodically to clean the screens. Be sure solenoid and automatically controlled valves are not getting wet. If such electrically operated valves short out, they must be replaced.

Metric Conversion Table

Length	1 inch 1 foot =	25.4 0.305	mm m
Area	1 ft² =	929.	cm²
Volume	1 gal	3.78	l
Mass	1 lb =	454	g
Flow	1 gpm =	225	l/hr
Energy	1 Btu =	1.054	kJ
Power Flux	1 Btu/hr ft² =	3.152	W/m²
Heat Transfer Rate	1 Btu/hr ft² °F =	5.68	W/m² °C
Thermal Conductivity	1 Btu/hr ft °F =	1.73	W/m °C
Temperature Difference	1 °F =	0.556	°C
Pressure	1 psi = 1 ft of head =	70.3 0.305	g/cm² m of head



6. REFERENCES

CONCRETE ASSOCIATIONS

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